Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 4
South Delta Null Zone Study

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4.1 Background

The State Water Resources Control Board (SWRCB) is in the process of reviewing and updating the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The review may result in the potential amendments to the South Delta (Figure 4-1) salinity objectives in the Bay-Delta Plan. Under the review process, SWRCB states that poor water circulation (null zones) contributes to bad water quality in the South Delta, and that the Central Valley Project (CVP) and State Water Project (SWP) are responsible for improving the water circulation conditions while raising water stage so that the farmers are able to divert water (State Water Resources Control Board, 2009).

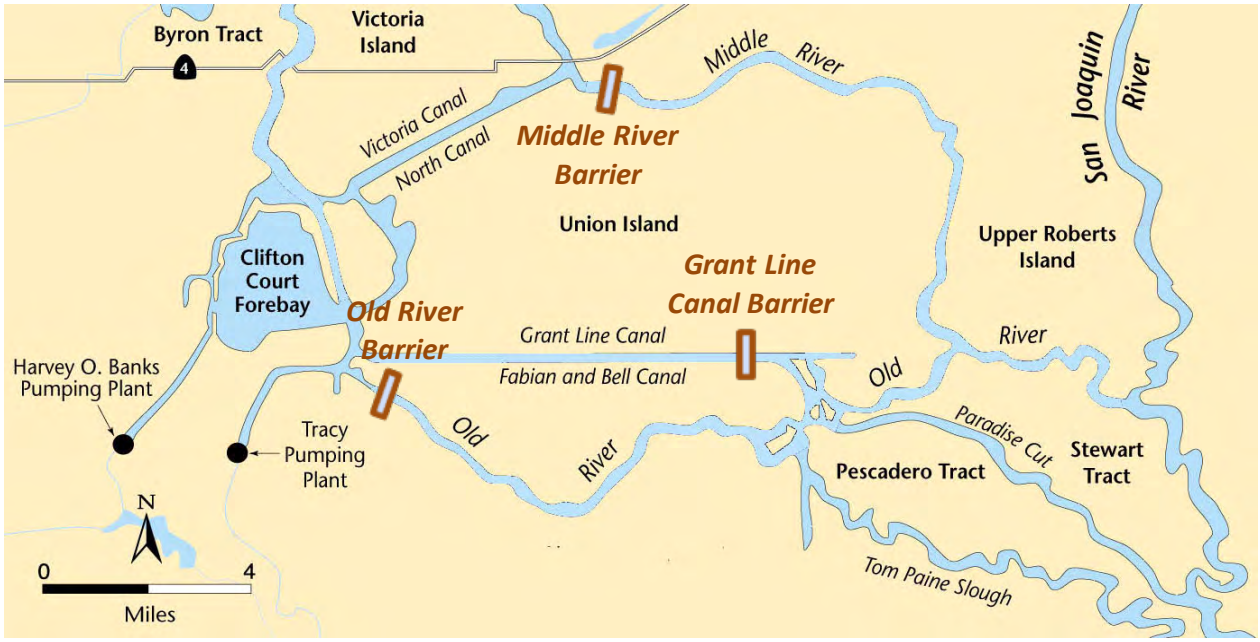


Figure 4-1 South Delta

4.2 Purpose

The purpose of this study is to analyze through hydrodynamic modeling whether and to what extent CVP and SWP exports and the agricultural temporary barriers actually influence the water levels (stage) and water circulation in South Delta. Specifically, the modeling analysis will address the following questions:

- How are null zones defined?
- Where are null zones (historically and with CVP/SWP exports)?
- How often do null zones occur (historically and with CVP/SWP exports)?
- How do CVP/SWP exports and barriers affect null zones?
- What are the stage impacts due to CVP/SWP exports and agricultural barriers?

4.3 Modeling Analysis Approach

The potential effect of CVP/SWP exports on water circulation and stage in the South Delta was examined using the Delta Simulation Model 2 (DSM2) (Delta Modeling Section, Online). A historical hydrology and barrier configuration was used as input and modified for each modeling scenario to evaluate the impacts of CVP/SWP exports and agricultural barriers. This model simulates flow, stage, and water quality in the Delta for both historical and hypothetical conditions. DSM2 has been calibrated or "tuned" to represent observed Delta flows, stages, and salinity (Nader-Tehrani & Shrestha, 2000). The model has a long history of applications for planning and management purposes in the Delta. Enhancements to the model are documented in annual reports to the SWRCB (annual reports available online at http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/annualreports.cfm).

DSM2 version 8.0.6 was used for this study. Specifically, the DSM2-HYDRO module was run with associated assumptions to produce flow and stage results; the model results were later post-processed for analysis and interpretation purposes (Figure 4-2).

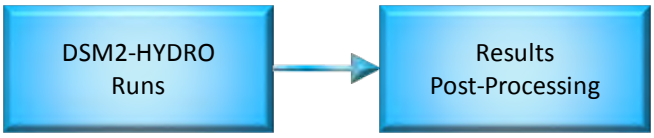


Figure 4-2 Process of DSM2 Modeling Analysis

4.3.1 Modeling Scenarios

Scenarios examined for this study include the combinations of three major factors:

- SWP export from the South Delta (Banks pumping plant)
- CVP export from the South Delta (Jones pumping plant)
- Operations of 3 barriers (Old River near Tracy, Middle River, and Grant Line Canal, generally installed between April and November)

Five modeling scenarios were investigated for this study. For each scenario, the model input for a historical simulation was modified so that the effects of that change could be analyzed. The 5 scenarios are listed below and are shown in Table 4-1:

- **NO_CVP_SWP_BARRIERS**: without CVP/SWP exports and without agricultural barriers[1].
- **NO_BARRIERS**: with historical CVP/SWP exports, but without agricultural barriers.
- **NO_SWP_BARRIERS**: with historical CVP export, but without SWP export and agricultural barriers.
- **NO_CVP_BARRIERS**: with historical SWP export, but without CVP export and agricultural barriers.
- **HISTORICAL**: with historical CVP/SWP exports and agricultural barrier operations.

[1] The Head of Old River Barrier (fish barrier) was not modified from its historical operation for any of the scenarios.

Table 4-1 Summary of Modeling Scenarios

Scenarios	SWP	CVP	Agricultural barriers
NO_CVP_SWP_BARRIERS	-	-	-
NO_BARRIERS	√	√	-
NO_SWP_BARRIERS[a]	-	√	-
NO_CVP_BARRIERS[a]	√	-	-
HISTORICAL	√	√	√

√ : Included - : Not Included
[a] The results of these two scenarios are available, but not presented in this report.

4.3.2 Modeling Assumptions and Considerations

Conceptually a null zone occurs at locations in the South Delta channels where flow and velocity in the channel approaches zero (or the flow is stagnant) and water quality degrades. This is a general definition of a null zone as it applies to the South Delta channels. However, according to DWR staff and stakeholders, there is no specific null zone definition that can easily be modeled. This definition would need to include the rate of velocity or flow, whether the flow or velocity is averaged over a tidal cycle, the time period over which that flow is near that low value, and the amount of water quality degradation. A clear definition is needed to carry out a thorough modeling analysis. Absent this definition and due to the limitations of accuracy in Delta diversion and return flows and quality, a simplified definition has been created for this study. This limited definition of a null zone can still provide information on the impacts of CVP/SWP exports and agricultural barriers on flow movement.

In this study, a null zone is defined if either of the following two conditions is met:

- **Condition 1**: in a DSM2 channel, if the tidal-averaged flow at the upstream end is flowing downstream and the tidal-averaged flow at the downstream end is upstream. (Figure 4-3, flows are shown as horizontal red arrows)
- **Condition 2**: in a DSM2 channel, if the tidal-averaged flow at the upstream end is flowing upstream and the tidal-averaged flow at the downstream end is downstream. (Figure 4-4, flows are shown as horizontal red arrows)

Figure 4-3 Condition 1 of Assumed Null Zone Definition

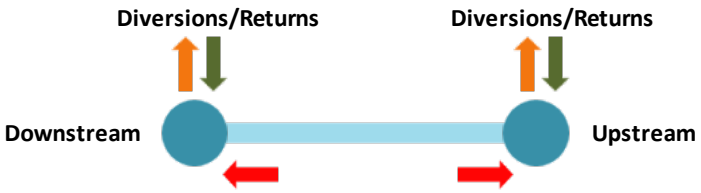


Figure 4-4 Condition 2 of Assumed Null Zone Definition

Also, for this modeling analysis, it is very important to recognize the following two considerations:

- The Without-CVP/SWP export simulations do not incorporate possible changes in upstream reservoir releases or other system operations as a result of cutting exports.
- DSM2 is limited by sparsely observed data for In–Delta diversions and returns. This may affect the null zone calculations.

Figure 4-5 shows the study area that is in the vicinity of the Old River and Middle River for assessing the null zone in this study. The area covers DSM2 channels 70 to 82 for Old River (about 10.9 miles in total), and channels 125 to 139 for Middle River (about 16.1 miles in total).

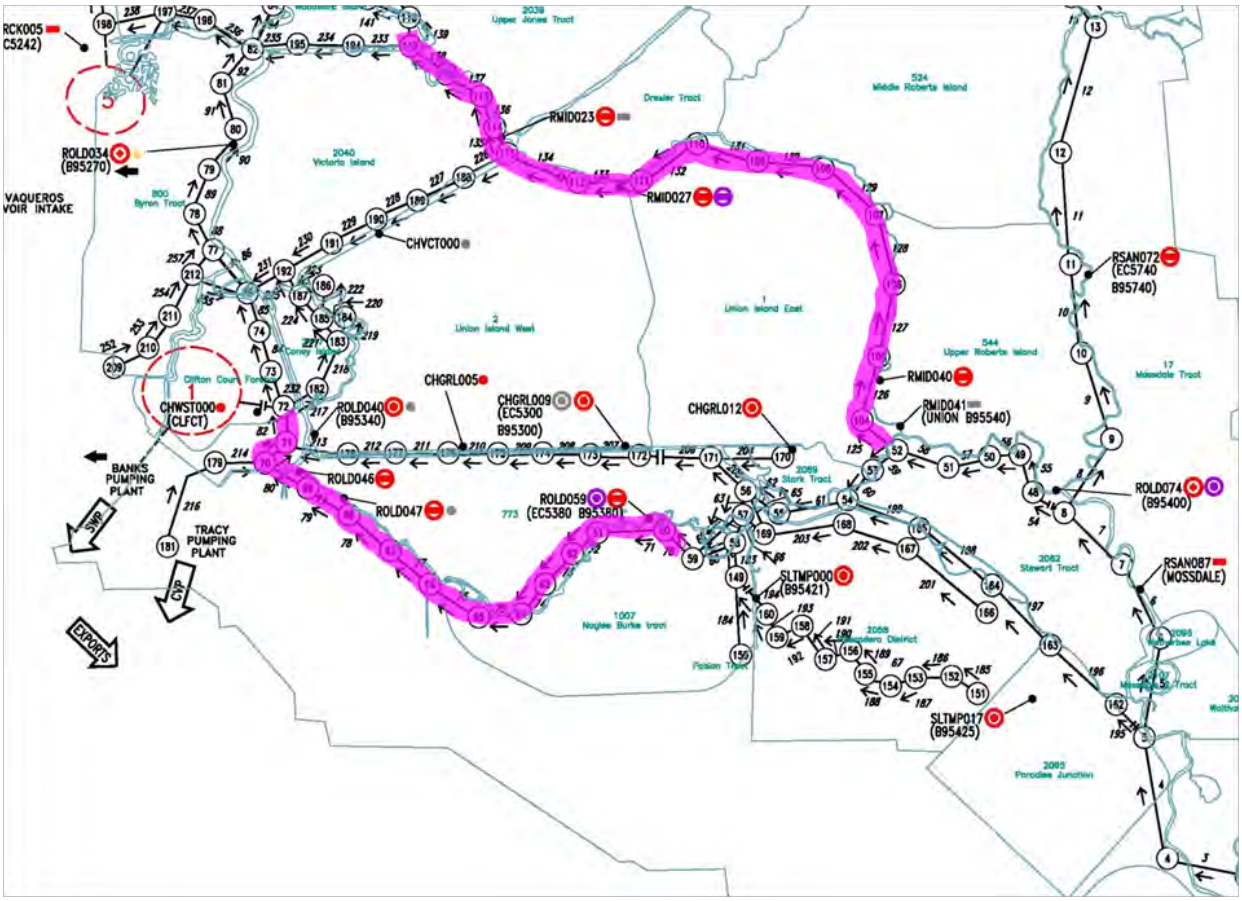


Figure 4-5 South Delta Channels included in Null Zone Assessment (Highlighted Area)

4.3.3 Simulation Periods

The model simulation period starts from January 1990 to December 2010 (21 years in total). These 21 years cover various hydrologic conditions, including 6 Wet years, 4 Above Normal years, 2 Below Normal years, 4 Dry years, and 5 Critical years according to the Sacramento Valley Index (California Department of Water Resources, 2011).

4.3.4 Model Results Interpretation

Because no historical records clearly identify where and how often null zones happen, no available data validate the adequacy of the assumed null zone definition and the associated model results. Therefore,

in this study, the model results are mainly used for comparison purposes. That is, the analysis focuses on the differences between scenarios, not the absolute values of the model results.

The model results are presented in terms of flow and stage for this study. Two scenario comparisons are discussed to assess the effects of CVP/SWP exports and/or the agricultural barriers' operations on water circulation and stage:

- A comparison between NO_CVP_SWP_BARRIERS and NO_ BARRIERS scenarios: this comparison shows the effects of CVP/SWP exports when no agricultural barriers are in place.
- A comparison between NO_CVP_SWP_BARRIERS and HISTORICAL scenarios: this comparison shows the effects of both CVP/SWP exports and the agricultural barriers.

4.4 Results and Findings

4.4.1 Flow

The DSM2 simulation results were post-processed to calculate the tidally-averaged flow (using the Godin filter method) for assessing the null zone conditions under different scenarios.

Figure 4-6 shows the null zone results for Old River and Middle River under the NO_CVP_SWP_BARRIERS and NO_ BARRIERS scenarios. The channel numbers in the DSM2 grid and the number of days in the 21 years simulation when a null zone is happening in each channel are shown and color-coded for the reader's convenience. Based on the assumed null zone definition, the results show that:

- Null zones occur in Old River and Middle River even when the CVP/SWP exports and the agricultural barriers are not in place (see results for the NO_CVP_SWP_BARRIERS scenario). The frequency of the null zone occurrence is relatively small when considering the entire 21 years (7,670 days in total). For example, in Middle River, the maximum number of days when a null zone happens is in channel 133 (134 days), which is about 1.75% of time over the 21 years.
- When the CVP/SWP exports are in place, the location and timing of null zone occurrences changes (see results for the NO_BARRIERS scenario). Similar to the NO_CVP_SWP_BARRIERS scenario, the frequency of null zone occurrences is relatively small when considering the entire 21 years. For example, in Middle River, the maximum number of days when a null zone happens is in channel 133 (141 days), which is about 1.84% of time over the 21 years.
- Comparing the NO_CVP_SWP_BARRIERS and the NO_BARRIERS scenario, in the entire 21-year simulation, the changes of occurrence frequency are between -22 to 4 days in Old River, and between -19 to 58 days in Middle River. The scale of the changes is considered relatively small.

Figure 4-7 shows the null zone results for Old River and Middle River under the NO_CVP_SWP_BARRIERS and HISTORICAL scenarios. The results show that when the CVP/SWP exports and agricultural barriers are in place, null zones happen; and compared with the NO_CVP_SWP_BARRIERS scenario, the timing and frequency of null zone occurrences change. In the entire 21-year simulation, the differences in frequency are between -22 to 13 days in Old River, and between -21 to 51 days in Middle River. The scale of the changes is considered relatively small.

The difference in null zone occurrences is further investigated for each month. The findings show that the changes are small when comparing scenarios under Without- and With-CVP/SWP exports and/or barriers (Figure 4-8 and Figure 4-9 show the results for July, when barriers are in place, as an example).

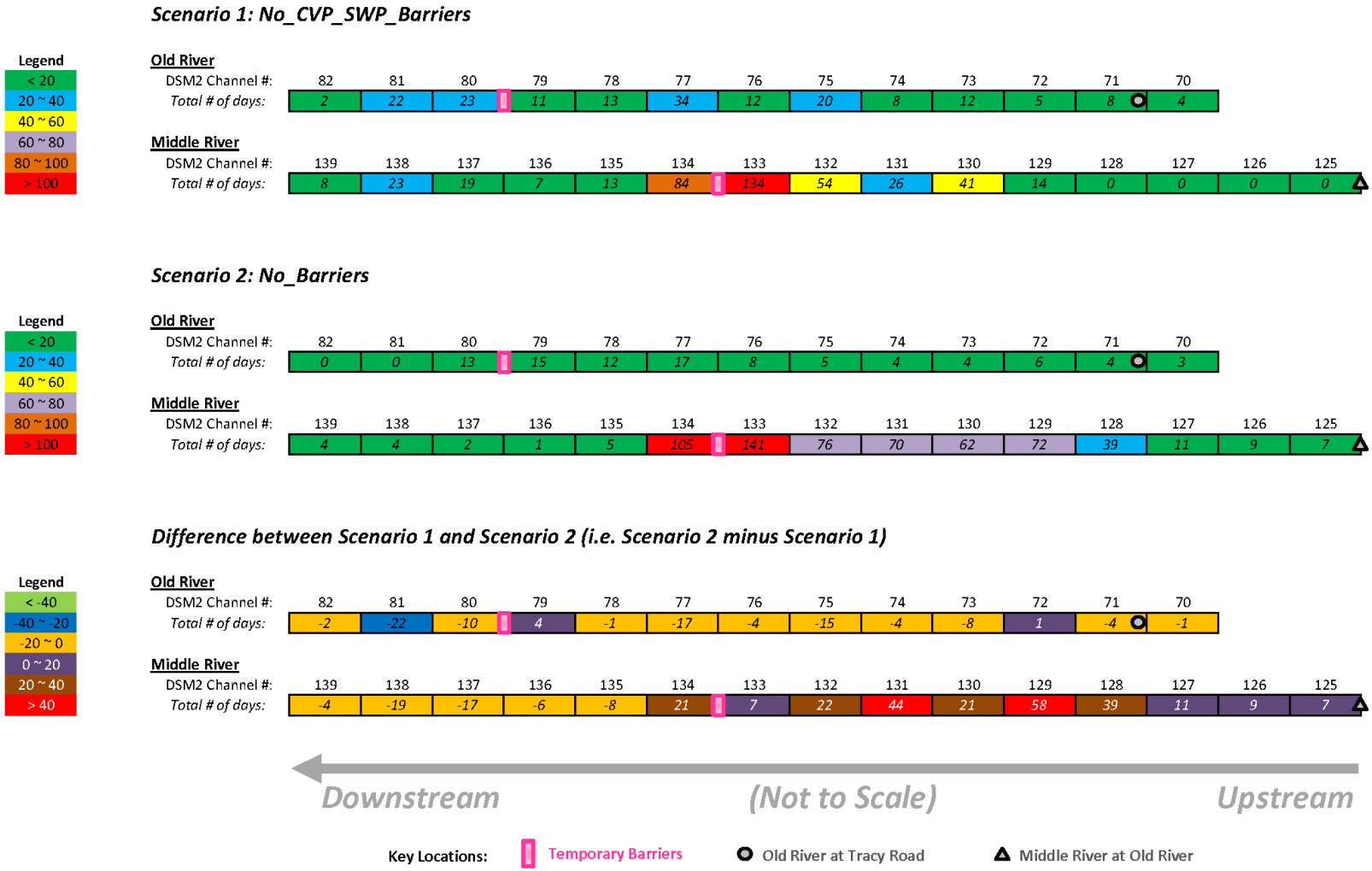


Figure 4-6 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and NO_BARRIERS Scenario (January 1990 to December 2010)

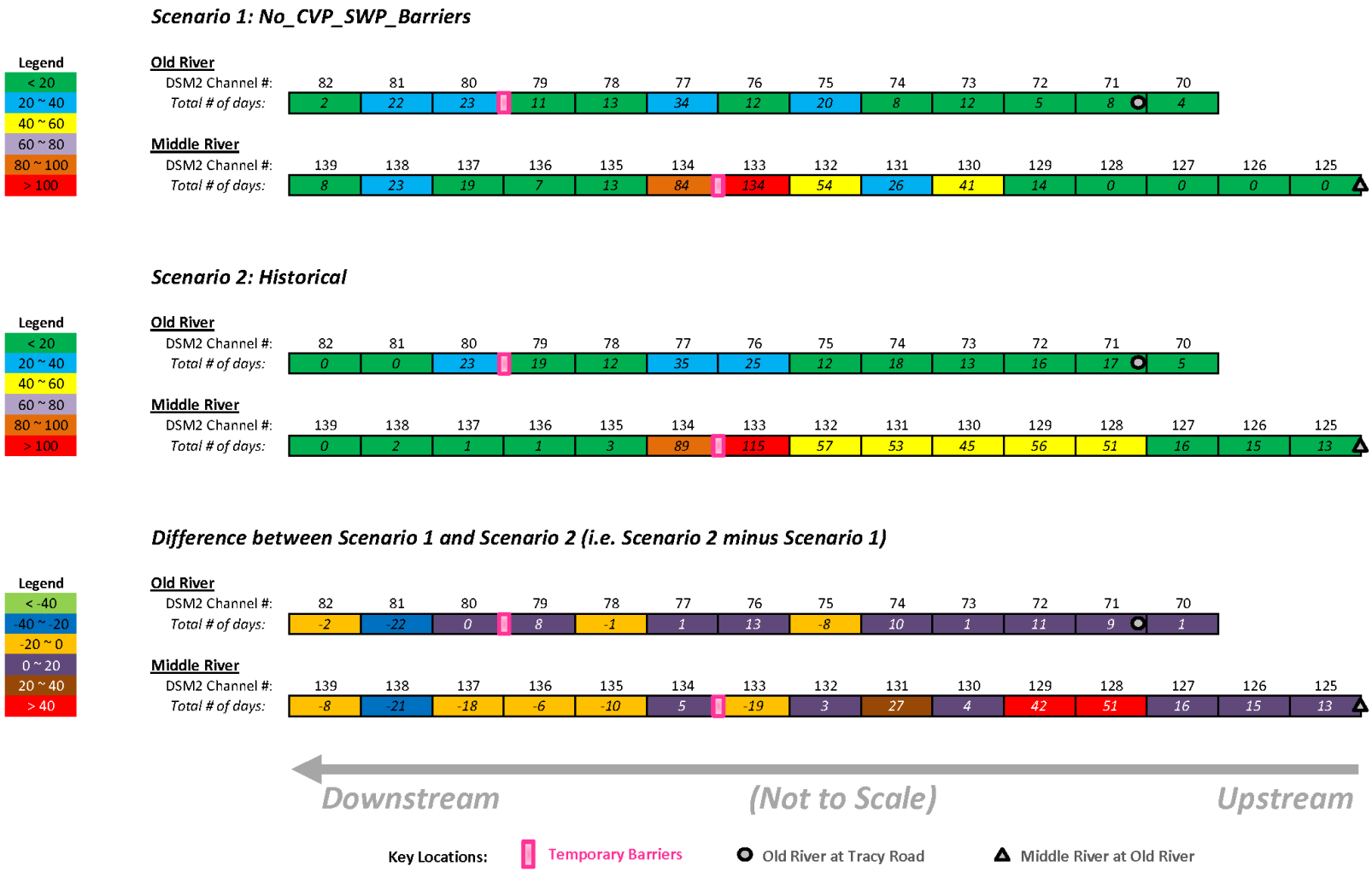


Figure 4-7 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and HISTORICAL Scenario (January 1990 to December 2010)

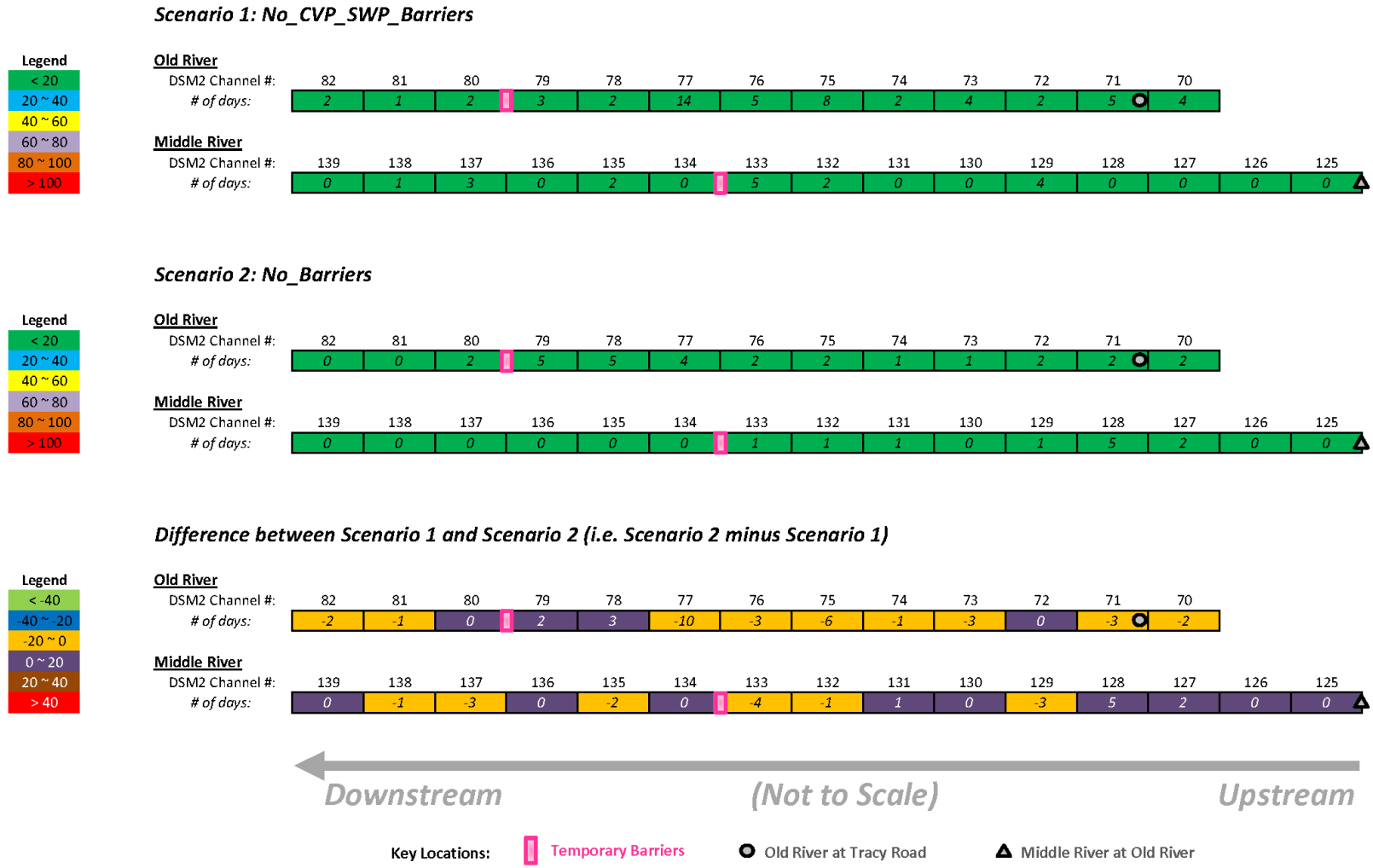


Figure 4-8 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and NO_BARRIERS Scenario for July Only (1990 to 2010)

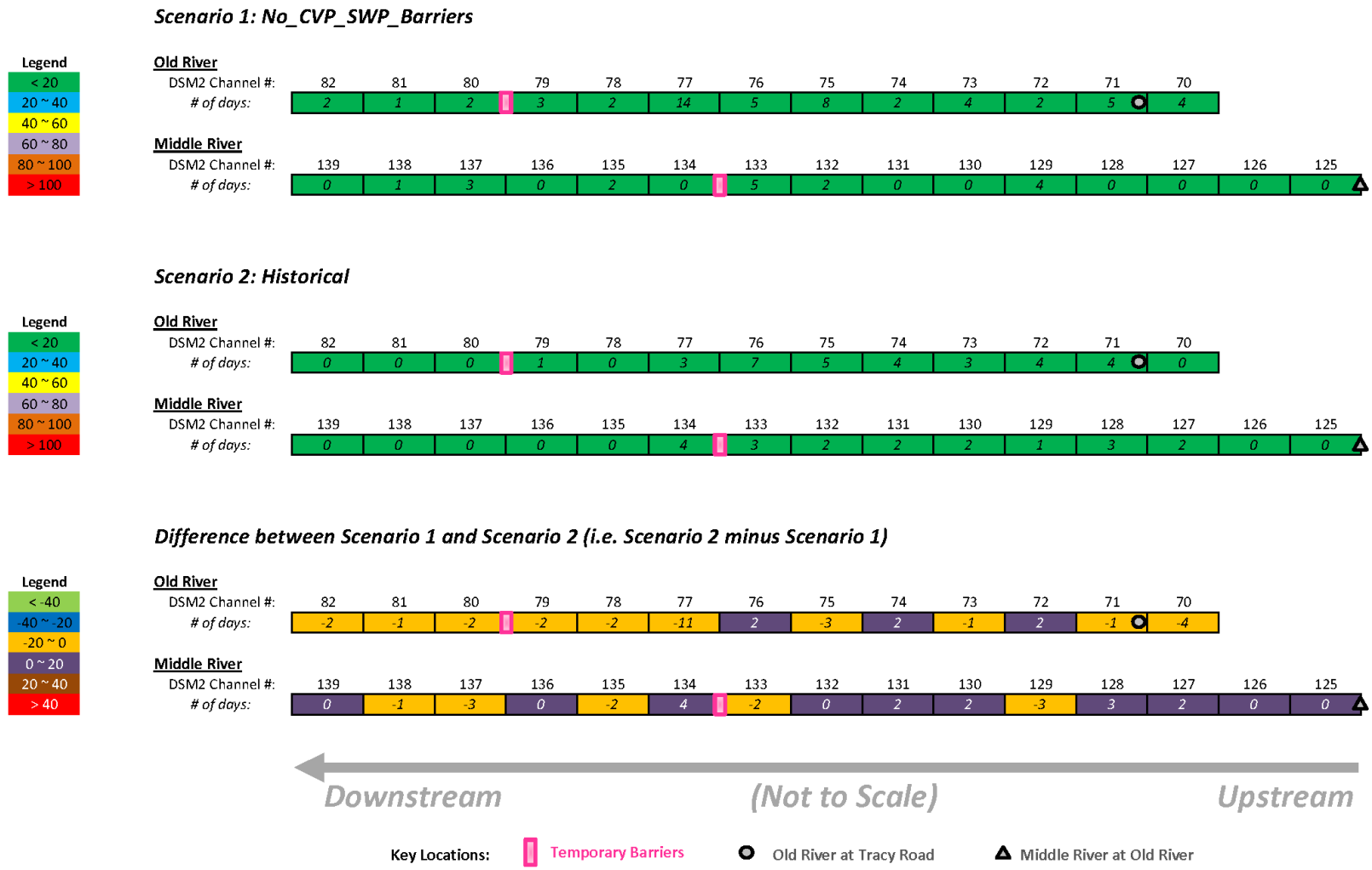


Figure 4-9 Model Results of Null Zone Occurrence for NO_CVP_SWP_BARRIERS and HISTORICAL Scenario for July Only (1990 to 2010)

4.4.2 Stage

In this study, the stage results are evaluated in terms of the daily minimum stage at 5 locations in the South Delta (Figure 4-10): (1) Old River at Tracy Road, (2) Middle River at Old River, (3) Old River Barrier, (4) Middle River Barrier, and (5) Grant Line Canal Barrier.

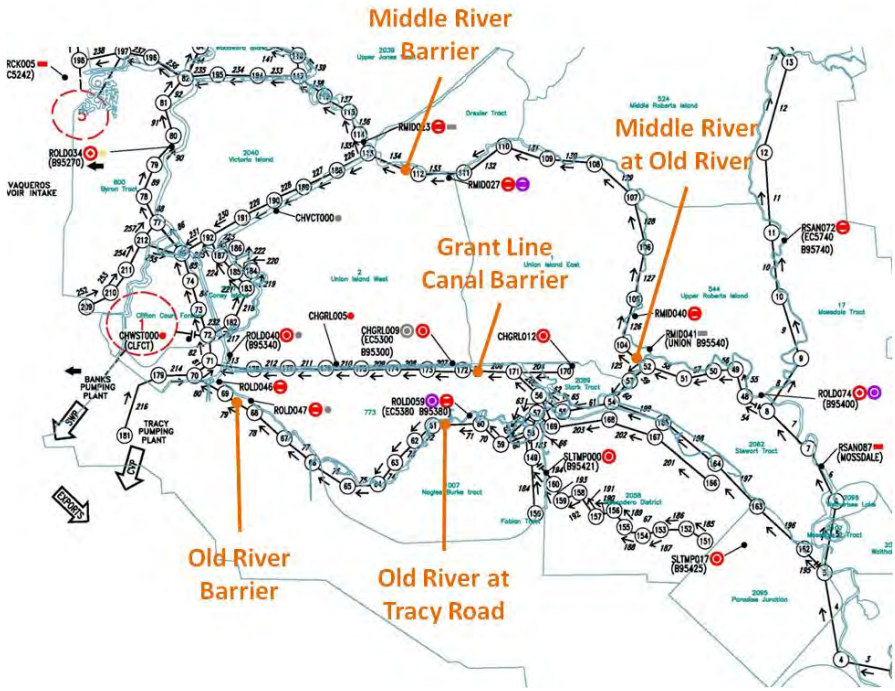
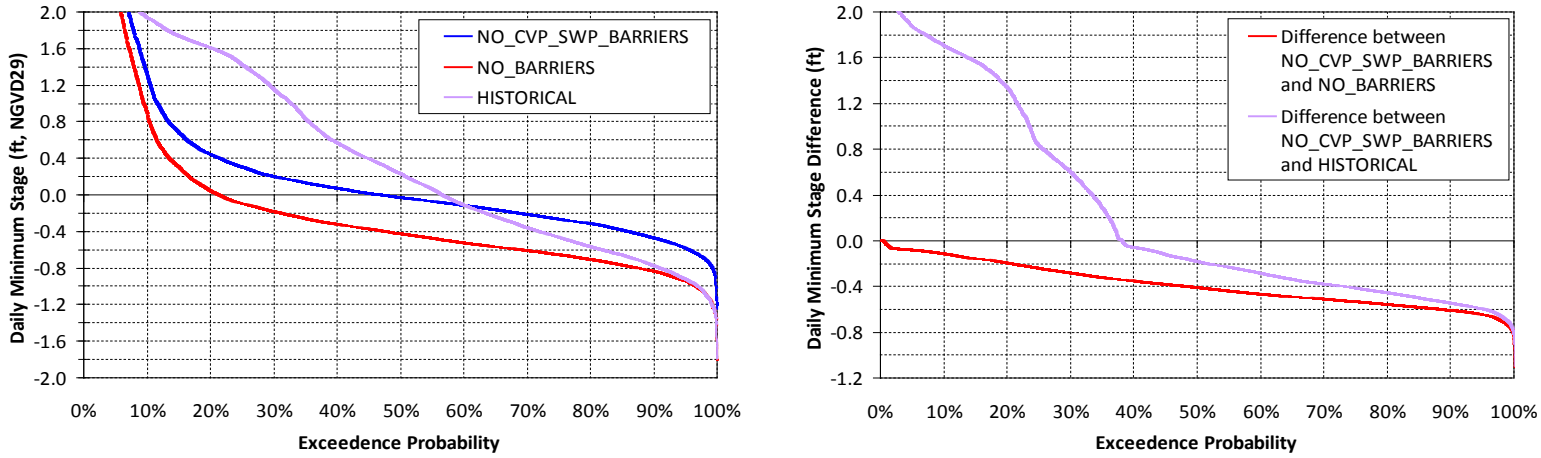


Figure 4-10 Locations of Stage Assessment in South Delta

Figure 4-11 shows the exceedence probability of the daily minimum stage results for the 21-year simulation. The plots on the left-hand side show the results under 3 scenarios. The plots on the right-hand side show the differences after comparing scenarios.

(a) Old River at Tracy Road



(b) Middle River at Old River

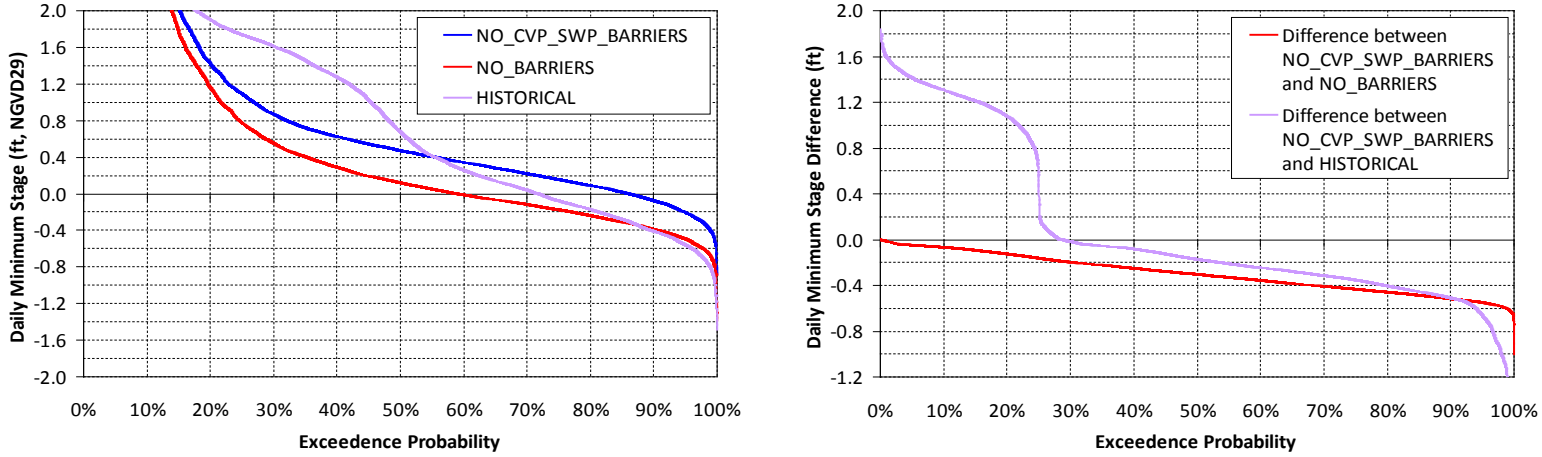
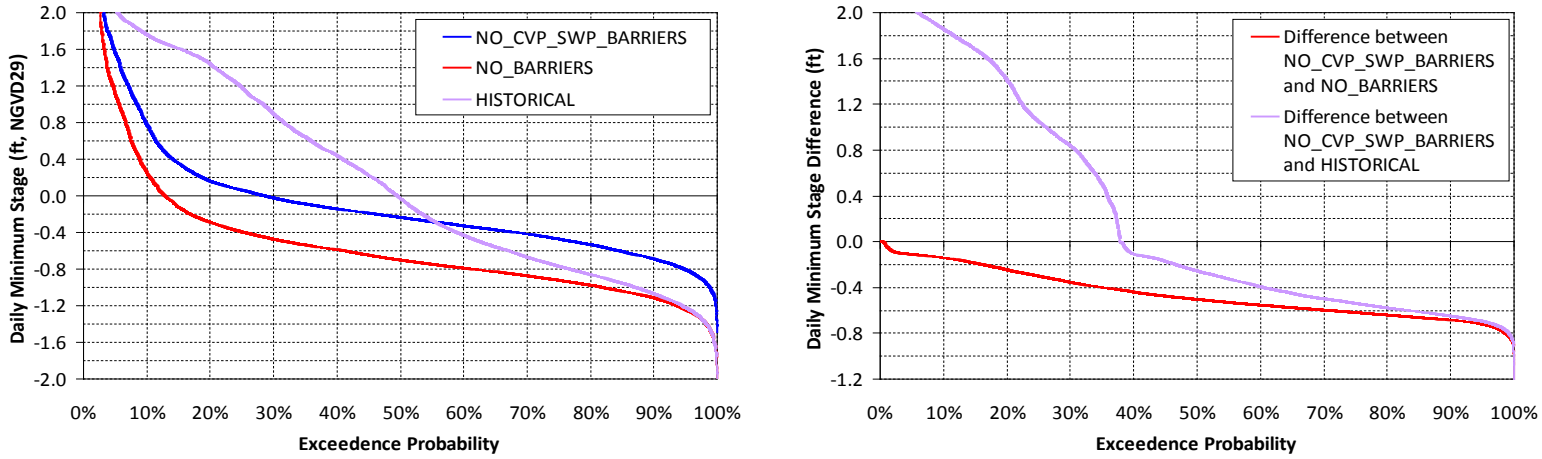


Figure 4-11 Daily Minimum Stage Results for the Entire 21 Years (1990 to 2010)

(c) Old River Barrier



(d) Middle River Barrier

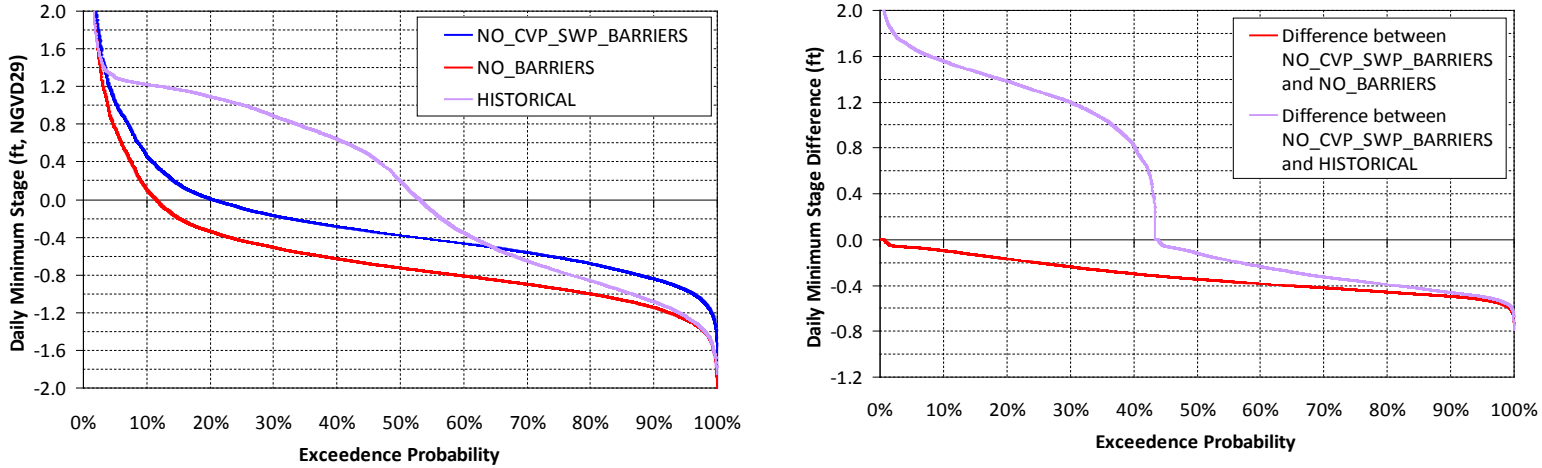


Figure 4-11 (cont'd) Daily Minimum Stage Results for the Entire 21 Years (1990 to 2010)

(e) Grant Line Canal Barrier

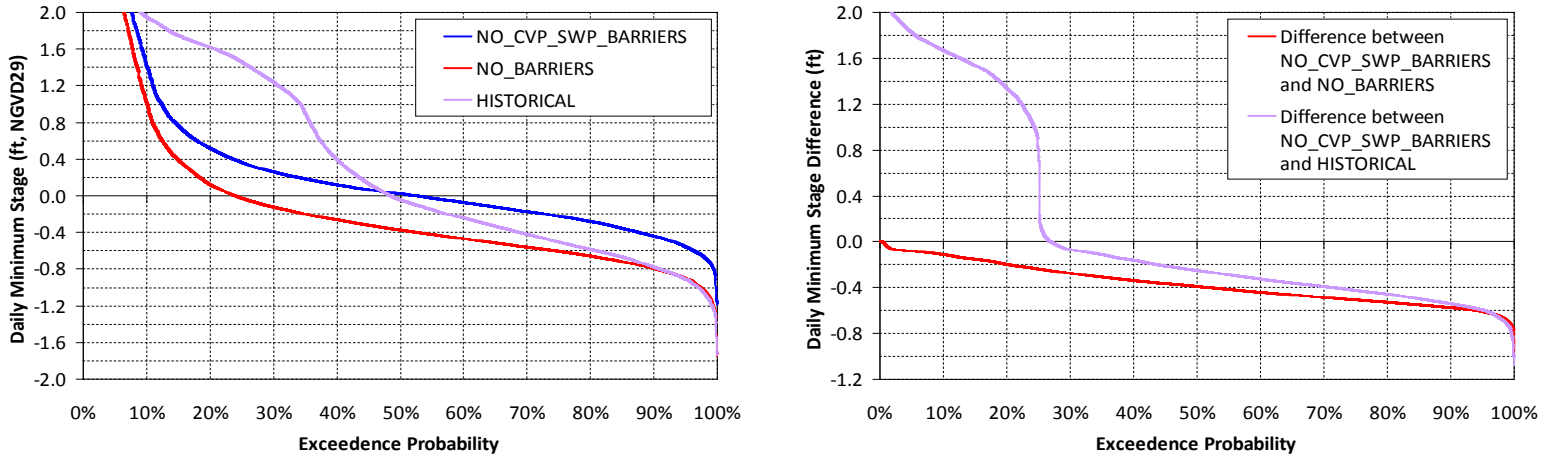


Figure 4-11 (cont'd) Daily Minimum Stage Results for the Entire 21 Years (1990 to 2010)

The results show that:

- When comparing the stage of NO_CVP_SWP_BARRIERS and NO_BARRIERS scenarios, the stage of the former is higher than that of the latter, i.e., the stage is lower when the CVP/SWP exports are in place. The exceedence probability curves provide the information of the frequency of stage and the differences between scenarios. For example, for the location of Old River at Tracy Road,
  - under the NO_BARRIERS scenario, the daily minimum stage that is equal to or less than zero (which is sometimes considered as a threshold for farmers so that water can be diverted) is about 79% of the time; and
  - the stage reduction (difference between the two scenarios) that is equal to or less than 0.4 feet occurs about 45% of the time.

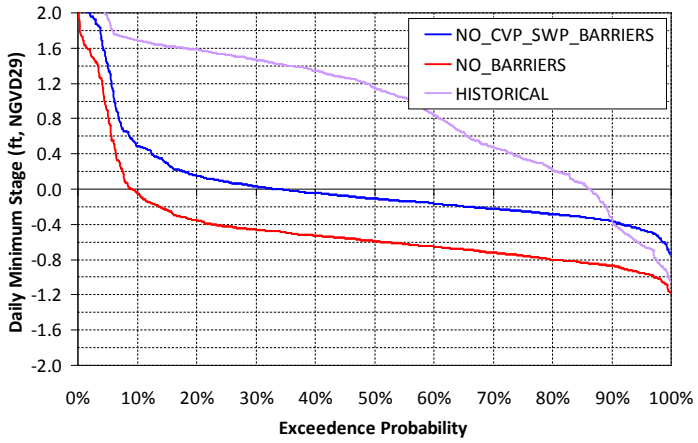
- When comparing the stage of NO_CVP_SWP_BARRIERS and HISTORICAL scenarios, the stage of the latter could be either higher or lower than that of the former depending on if the agricultural barriers are operated. The stage is higher when both CVP/SWP exports and agricultural barriers are considered; the stage is lower when only CVP/SWP exports are in place. The exceedence probability curves provide the information of the frequency of stage and the differences between scenarios. For example, for the location of Old River at Tracy Road,
  - under HISTORICAL scenario, the daily minimum stage that is equal to or less than zero (which is sometimes considered as a threshold for farmers so that water can be diverted) occurs about 44% of the time; and
  - the stage reduction (difference between the two scenarios) that is equal to or less than 0.2 feet is about 50% of the time.

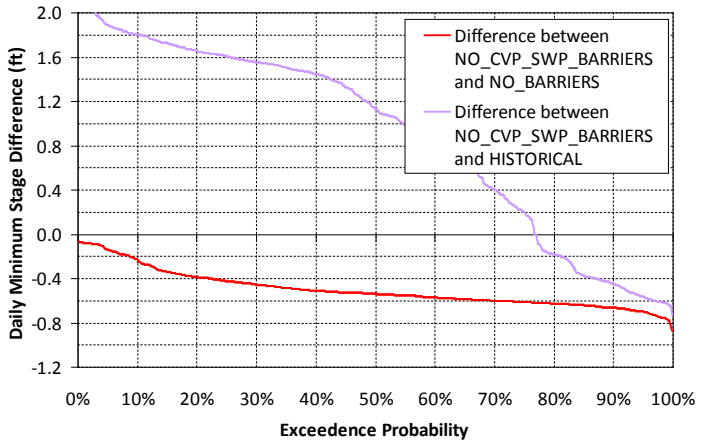
The daily minimum stage is further investigated for each month. Figure 4-12 shows the results for July (when agricultural barriers are in place) as an example.

- When comparing the stage of the NO_CVP_SWP_BARRIERS and NO_BARRIERS scenarios, the stage under the former is higher than that of the latter. For example, the exceedence probability curves for the location of Old River at Tracy Road show that
  - under the NO_BARRIERS scenario, the daily minimum stage that is equal to or less than zero occurs about 91% of the time; and
  - the stage reduction (difference between the two scenarios) that is equal to or less than 0.6 feet occurs about 71% of the time.

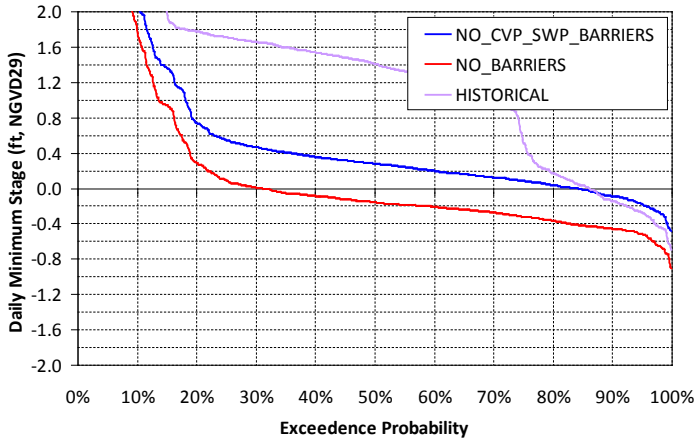
- When comparing the stage under the NO_CVP_SWP_BARRIERS and HISTORICAL scenarios, the stage of the latter is higher than that of the former most of the time because the agricultural barriers are operated. For example, the exceedence probability curves for the location of Old River at Tracy Road show that
  - under the HISTORICAL scenario, the daily minimum stage that is equal to or less than zero occurs about 14% of the time; and
  - the stage increase (difference between the two scenarios) that is equal to or greater than 0.4 feet occurs about 70% of the time.

(a) Old River at Tracy Road





(b) Middle River at Old River



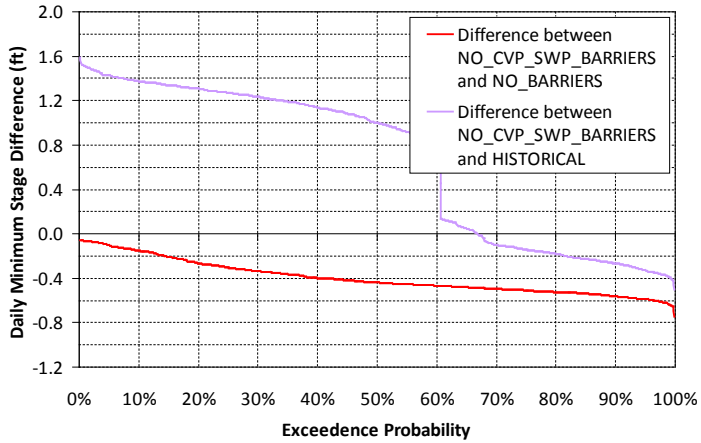
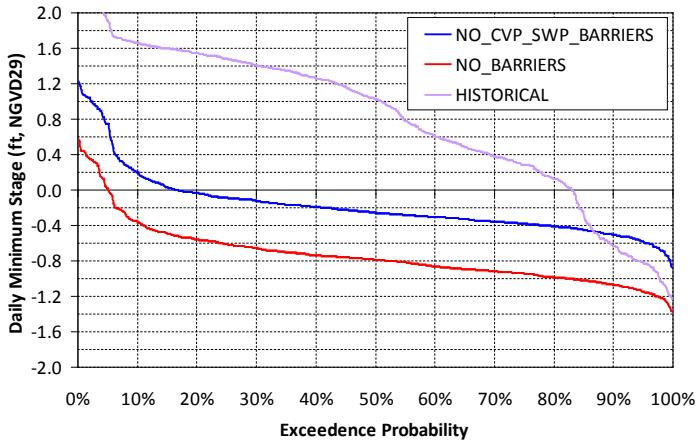
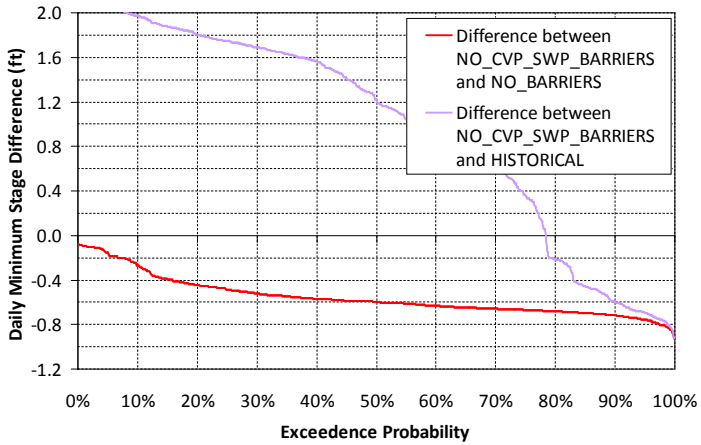


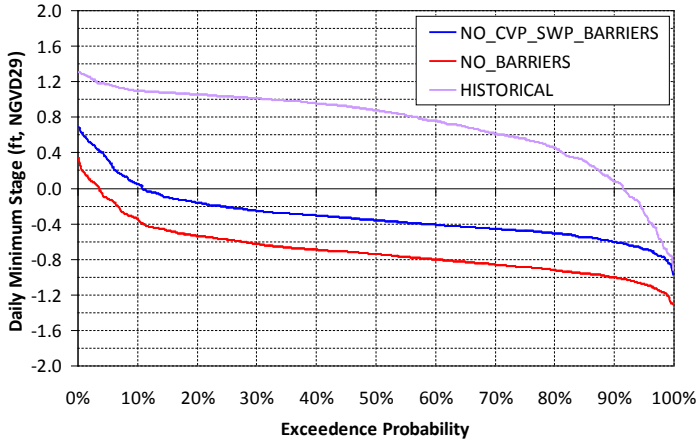
Figure 4-12 Daily Minimum Stage Results for July Only (1990 to 2010)

(c) Old River Barrier





(d) Middle River Barrier



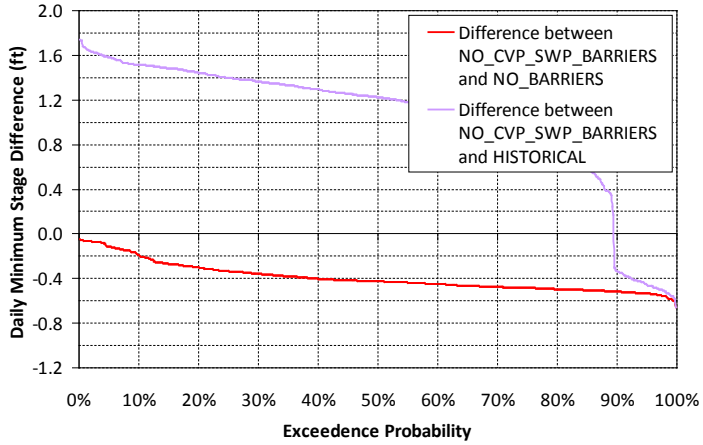


Figure 4-12 (cont'd) Daily Minimum Stage Results for July Only (1990 to 2010)

(e) Grant Line Canal Barrier

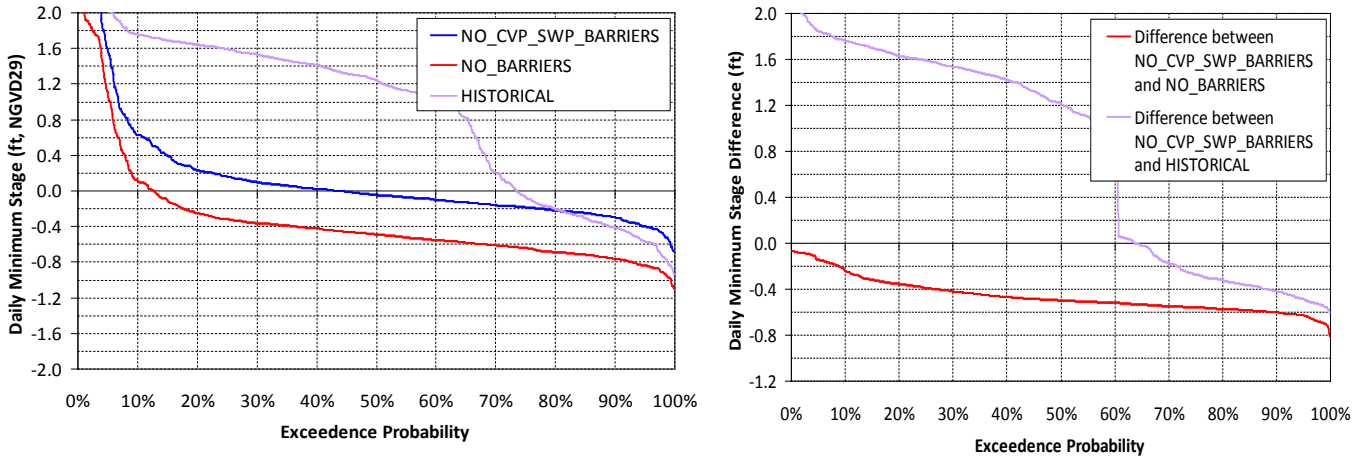


Figure 4-12 (cont'd) Daily Minimum Stage Results for July Only (1990 to 2010)

4.5 Conclusions

The following summarizes the conclusions of this study:

- Based on the assumed null zone definition, the modeling results show that null zones could happen even when CVP/SWP exports and/or barriers are not in place.
- When CVP/SWP exports are in place, the locations and occurrence frequency of null zones change. When compared to the Without-CVP/SWP exports scenario, the difference is relatively small.
- When CVP/SWP exports and agricultural barriers are in place, the locations and occurrence frequency of null zones change. When compared to the Without-CVP/SWP exports scenario, the difference is relatively small.
- Agricultural barrier operations raise the daily minimum water levels during irrigation seasons.

4.6 References

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